

What Is Claimed Is:

1. A method for manufacturing a ferroelectric thin film device, comprising the steps of:

forming a bottom electrode film containing at least iridium on a surface preparation layer whose main component is zirconium oxide;

laminating an ultra-thin titanium layer over said bottom electrode; and

forming a crystallized ferroelectric thin film by forming an amorphous layer containing elemental metal and elemental oxygen that constitute a ferroelectric over said titanium layer, and heat treating said amorphous layer,

wherein the orientation of said ferroelectric thin film is controlled by adjusting the film thickness in the lamination of said titanium layer.

2. The method for manufacturing a ferroelectric thin film device defined in Claim 1, wherein the priority orientation of said ferroelectric thin film is set to (100) by keeping the film thickness to at least 2 nm and less than 10 nm in the lamination of said titanium layer.

3. The method for manufacturing a ferroelectric thin film device defined in Claim 1, wherein the priority orientation of said ferroelectric thin film is set to (111) by

keeping the film thickness to at least 10 nm and less than 20 nm in the lamination of said titanium layer.

4. The method for manufacturing a ferroelectric thin film device defined in any of Claims 1 to 3, wherein the step of forming said ferroelectric thin film is a step of forming a film by sol-gel method from a ferroelectric whose constituent components are at least titanium and lead.

5. The method for manufacturing a ferroelectric thin film device defined in Claim 4, wherein said ferroelectric is lead titanate zirconate.

6. The method for manufacturing a ferroelectric thin film device defined in any of Claims 1 to 5, wherein the step of forming said ferroelectric thin film is a step of forming a single layer of an iridium film, or using platinum and iridium to form a laminate film comprising an (iridium layer)/(platinum layer), a (platinum layer)/(iridium layer), or an (iridium layer)/(platinum layer)/(iridium layer), in that order starting at said surface preparation layer.

7. The electromechanical transducer, obtained by the method according to Claim 2 or 3.

8. An ink jet recording head, comprising:

the electromechanical transducer defined in Claim 7;

a pressure chamber whose internal volume is varied by the mechanical displacement of said electromechanical transducer;  
and

discharge outlets that communicate with said pressure chamber and from which ink droplets are discharged.

9. The ink jet recording head according to Claim 8, wherein said discharge outlets are arranged in rows that are more or less parallel to the main scanning direction.

10. An ink jet printer whose printing mechanism is equipped with the ink jet recording head according to Claim 8 or 9.

11. A method for manufacturing an ink jet recording head, comprising the steps of:

forming a surface preparation layer whose main component is zirconium oxide on a silicon substrate surface, either directly or via a diaphragm film;

forming a bottom electrode containing at least iridium over said surface preparation layer;

laminating a titanium layer whose film thickness is at least 10 nm and less than 20 nm over said bottom electrode;

forming a ferroelectric thin film having a priority orientation of (111) by forming an amorphous film containing

the elemental metal and elemental oxygen that constitute the ferroelectric over said titanium layer and then heat treating said amorphous film;

manufacturing an electromechanical conversion device by forming an top electrode over said ferroelectric thin film; and

separating the electromechanical transducer so as to line up with the position where the mechanical displacement of the electromechanical transducer can be imparted to the pressure chamber.

12. A method for manufacturing an ink jet recording head, comprising the steps of:

forming a surface preparation layer whose main component is zirconium oxide over a silicon substrate surface, either directly or via a diaphragm film;

forming a bottom electrode containing at least iridium over said surface preparation layer;

laminating a titanium layer with a thickness of at least 2 nm and less than 10 nm over said bottom electrode;

forming a ferroelectric thin film having a priority orientation of (100) by forming an amorphous layer containing elemental metal and elemental oxygen that constitute a ferroelectric over said titanium layer, and heat treating said amorphous layer;

manufacturing an electromechanical transducer by forming an top electrode over said ferroelectric thin film; and

separating the electromechanical transducer so as to line up with the position where the mechanical displacement of the electromechanical transducer can be imparted to the pressure chamber.

13. The method for manufacturing an ink jet recording head according to Claim 11 or 12, wherein the step of forming said ferroelectric thin film is a step of forming a film by sol-gel method from a ferroelectric whose constituent components are at least titanium and lead.

14. The method for manufacturing a ferroelectric thin film device defined in Claim 13, wherein said ferroelectric is lead titanate zirconate.

15. The method for manufacturing an ink jet recording head defined in any of Claims 11 to 14, wherein the step of forming said bottom electrode is a step of forming a single layer of an iridium film, or using platinum and iridium to form a laminate film comprising an (iridium layer)/ (platinum layer), a (platinum layer)/(iridium layer), or an (iridium layer)/(platinum layer)/ (iridium layer), in that order starting at said surface preparation layer.

16. A nonvolatile ferroelectric memory device in which a ferroelectric thin film manufactured by the method according to Claim 2 or 3 serves as a capacitor.

17. A method for manufacturing a nonvolatile ferroelectric memory device, comprising the steps of:

forming a bottom electrode containing at least iridium over a surface preparation layer whose main component is zirconium oxide;

laminating a titanium layer whose film thickness is at least 2 nm and less than 10 nm over said bottom electrode; and

forming a capacitor insulating film having a priority orientation of (100) by forming an amorphous film containing the elemental metal and elemental oxygen that constitute the ferroelectric over said titanium layer and then heat treating said amorphous film.

18. The method for manufacturing a nonvolatile ferroelectric memory device according to Claim 17, wherein the step of forming said capacitor insulating film is a step of forming a film by sol-gel method from a ferroelectric whose constituent components are at least titanium and lead.

19. The method for manufacturing a nonvolatile ferroelectric memory device defined in Claim 18, wherein said ferroelectric is lead titanate zirconate.

20. The method for manufacturing a nonvolatile ferroelectric memory device defined in any of Claims 17 to 19, wherein the step of forming said bottom electrode is a step of forming a single layer of an iridium film, or using platinum and iridium to form a laminate film comprising an (iridium layer)/(platinum layer), a (platinum layer)/(iridium layer), or an (iridium layer)/(platinum layer)/ (iridium layer), in that order starting at said surface preparation layer.

21. A method for manufacturing an electromechanical transducer, comprising the steps of:

forming a bottom electrode containing at least iridium over a surface preparation layer whose main component is zirconium oxide;

laminating a titanium layer with a thickness of at least 2 nm and less than 10 nm over said bottom electrode; and

forming a ferroelectric thin film having a priority orientation of (100) by forming an amorphous layer containing elemental metal and elemental oxygen that constitute a ferroelectric over said titanium layer, and heat treating said amorphous layer.

22. The method for manufacturing an electromechanical transducer to Claim 21, wherein the step of forming said ferroelectric thin film is a step of forming a film by sol-gel

method from a ferroelectric whose constituent components are at least titanium and lead.

23. The method for manufacturing an electromechanical transducer defined in Claim 22, wherein said ferroelectric is lead titanate zirconate.

24. The method for manufacturing an electromechanical transducer defined in any of Claims 21 to 23, wherein the step of forming said bottom electrode is a step of forming a single layer of an iridium film, or using platinum and iridium to form a laminate film comprising an (iridium layer)/(platinum layer), a (platinum layer)/(iridium layer), or an (iridium layer)/(platinum layer)/(iridium layer), in that order starting at said surface preparation layer.

25. A method for manufacturing an electromechanical transducer, comprising the steps of:

forming a bottom electrode composed of iridium alone over a surface preparation layer whose main component is zirconium oxide;

laminating a titanium layer whose film thickness is at least 15 nm and less than 30 nm over said bottom electrode; and

forming a crystallized ferroelectric thin film by forming an amorphous film containing the elemental metal and elemental



oxygen that constitute the ferroelectric over said titanium layer and then heat treating said amorphous film.

26. A method for manufacturing an electromechanical transducer, comprising the steps of:

forming a bottom electrode composed of iridium alone over a surface preparation layer whose main component is zirconium oxide;

laminating an ultra-thin titanium layer over said bottom electrode; and

forming a crystallized ferroelectric thin film by forming an amorphous film containing the elemental metal and elemental oxygen that constitute the ferroelectric over said titanium layer and then heat treating said amorphous film,

wherein the priority orientation of the ferroelectric thin film is controlled to the (111) plane or the (110) plane by adjusting the thickness of said titanium layer to at least 15 nm and less than 30 nm.

27. The method for manufacturing an electromechanical transducer according to Claim 25 or 26, wherein the step of forming said ferroelectric thin film is a step of forming a film by sol-gel method or MOD method.

28. An electromechanical transducer comprising a ferroelectric thin film sandwiched between an top electrode and a bottom electrode,

said electromechanical transducer comprising an adhesive layer formed from an alloy containing an anti-diffusion metal and formed between said bottom electrode and the surface where said transducer is installed; and

an anti-diffusion layer formed from an alloy containing said anti-diffusion metal and formed between said bottom electrode and said ferroelectric thin film.

29. The electromechanical transducer according to Claim 28, wherein said anti-diffusion metal is selected from the group consisting of iridium, palladium, rhodium, ruthenium, and osmium.

30. The electromechanical transducer according to Claim 28, wherein said adhesive layer is an alloy of said anti-diffusion metal and the metal that constitutes said bottom electrode.

31. The electromechanical transducer according to Claim 28, wherein said anti-diffusion layer is an alloy of said anti-diffusion metal and an adhesive metal that is either titanium or chromium.

32. The electromechanical transducer according to Claim 28, wherein said bottom electrode consists of platinum.

33. The electromechanical transducer according to Claim 28, wherein said ferroelectric thin film is formed in a thickness of at least 1  $\mu\text{m}$ .

34. An ink jet recording head, wherein the electromechanical transducer according to any of Claims 28 to 33 is installed on a diaphragm film formed on at least one side of a pressure chamber filled with ink.

35. The ink jet recording head according to Claim 34, wherein said diaphragm film is constituted by the lamination of a silicon oxide film and a zirconium oxide film.

36. An ink jet printer, wherein the ink jet recording head according to either Claim 34 or 35 is provided as an ink discharge means.

37. A method for manufacturing an electromechanical transducer comprising a ferroelectric thin film sandwiched between an top electrode and a bottom electrode, comprising the steps of:

forming an adhesive metal layer composed of an adhesive metal over the surface where said transducer is installed;

forming a first anti-diffusion metal layer composed of an anti-diffusion metal over said adhesive metal layer;

forming said bottom electrode over said anti-diffusion metal layer;

forming a second anti-diffusion metal layer composed of said anti-diffusion metal over said bottom electrode; and

baking said ferroelectric thin film while this ferroelectric thin film is formed over said second anti-diffusion metal layer, and thereby diffusing said adhesive metal all the way to said second anti-diffusion metal layer and producing an anti-diffusion layer at the location of said second anti-diffusion metal layer, promoting the alloying of said anti-diffusion metal and said bottom electrode, and producing an adhesive layer at the location of said adhesive metal layer and first anti-diffusion metal layer.

38. The method for manufacturing a electromechanical transducer according to Claim 37, wherein a metal selected from the group consisting of iridium, palladium, rhodium, ruthenium, and osmium is used as the anti-diffusion metal.

39. The method for manufacturing a electromechanical transducer according to Claim 37, wherein either titanium or chromium is used as said adhesive metal.

40. An electromechanical transducer comprising a bottom electrode and a ferroelectric thin film, comprising:

an interlayer formed from a compound selected from the group consisting of zirconium oxide, tantalum oxide, silicon nitride, and aluminum oxide and formed on the surface where said transducer is installed; and

a bottom electrode formed over said interlayer,  
said bottom electrode comprising:

a first layer composed of an alloy of iridium and a specific metal and provided over said interlayer; and

a second layer containing iridium and provided over said first layer.

41. An electromechanical transducer comprising a bottom electrode and a ferroelectric thin film, comprising:

an interlayer formed from a compound selected from the group consisting of zirconium oxide, tantalum oxide, silicon nitride, and aluminum oxide and formed on the surface where said transducer is installed; and

a bottom electrode formed over said interlayer,  
said bottom electrode comprising:

a first layer containing a specific metal and provided over said interlayer; and

a second layer containing iridium and provided over said first layer.

42. The electromechanical transducer according to Claim 41, wherein said second layer is constituted such that the iridium diffused from the lower layer side during baking is separated from the iridium present since before baking.

43. The electromechanical transducer according to either Claim 40 or 41, wherein an adhesive layer comprising a metal that adheres to said interlayer and said bottom electrode is further formed between these two layers.

44. The electromechanical transducer according to Claim 43, wherein the volumetric ratio in said bottom electrode accounted for by the alloy containing iridium is at least  $2/5$  and no more than  $4/5$ .

45. An ink jet recording head, wherein the electromechanical transducer according to any of Claims 40 to 44 is provided as an actuator over the diaphragm film which is said surface where the transducer is installed.

46. An ink jet printer, comprising the ink jet recording head according to Claim 45 as a printing means.

47. A method for manufacturing an electromechanical transducer comprising a bottom electrode and a ferroelectric thin film, comprising the steps of:

using a compound selected from the group consisting of zirconium oxide, tantalum oxide, silicon nitride, and aluminum oxide to form an interlayer on the surface where said transducer is installed;

forming a bottom electrode over said interlayer;

forming a ferroelectric thin film precursor over said bottom electrode; and

baking,

said step of forming the bottom electrode comprising the steps of:

using iridium to form a first iridium layer;

using a specific metal to form a metal layer over said first iridium layer; and

using iridium to form a second iridium layer over said metal layer, and

said baking step being a step of forming said ferroelectric thin film precursor and then baking it at a temperature of 750°C or lower, thereby diffusing the iridium of said first iridium layer and converting said first iridium layer and said metal layer into an alloy layer in which iridium is alloyed with said metal.

48. A method for manufacturing an electromechanical transducer comprising a bottom electrode and a ferroelectric thin film, comprising the steps of:

using a compound selected from the group consisting of zirconium oxide, tantalum oxide, silicon nitride, and aluminum oxide to form an interlayer on the surface where said transducer is installed;

forming a bottom electrode over said interlayer;

forming a ferroelectric thin film precursor over said bottom electrode; and

baking,

said step of forming the bottom electrode comprising the steps of:

using iridium to form a first iridium layer;

using a specific metal to form a metal layer over said first iridium layer;

using iridium to form a second iridium layer over said metal layer; and

forming a ferroelectric thin film over said second iridium layer, and

said baking step being a step of forming said ferroelectric thin film precursor and then baking it at a temperature higher than 750°C, thereby diffusing the iridium of said first iridium layer and moving the iridium of said first iridium layer to said second iridium layer.

49. The method for manufacturing an electromechanical transducer according to Claim 47 or 48, wherein the ratio of the thickness of said first iridium layer prior to baking to



the thickness of said bottom electrode overall is set to be between 1/3 and 4/5.

50. The method for manufacturing an electromechanical transducer according to any of Claims 47 to 49, further comprising the step of:

using a metal that will adhere to the layers above and below to form an adhesive layer between said bottom electrode and said interlayer.

51. The method for manufacturing an electromechanical transducer according to Claim 50, wherein said step of forming a bottom electrode is a step of forming a film such that the following relationship is satisfied:

$$dT = 3.6 \times d_0 + 2.4 \times d_1 + 0.8 \times d_2 + 2.3 \times d_3$$

when we let  $d_0$  be the thickness of said adhesive layer prior to baking,  $d_1$  be the thickness of said first iridium layer,  $d_2$  be the thickness of said metal layer,  $d_3$  be the thickness of said second iridium layer, and  $dT$  be the thickness of said bottom electrode overall after baking.